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Comparative Analysis of Reliability Models of a Cable Plant Portraying Summer and Winter Operating Strategy

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Abstract. The paper presents a comparative analysis between the profits of two reliability models of a plant, manufacturing electrical cables. Model-I is based on operating the plant for 24 hours without resting machines during summer season, whereas, Model-II is based on 16 hours of operation followed by 8 hours of rest period during winter season. Specific season based operational strategies being adopted to address the demand based production of the cables. Real maintenance data are used for estimating the optimized reliability indices and comparison of profits. Semi-Markov processes and regenerative point techniques are used to carry out the analysis. Essential graphs are plotted to demonstrate the results.

Keywords: cable plant, regenerative processes, reliability, semi-Markov processes.

1 Introduction

Significant contribution has been made to the field of reliability by a number of researchers while analysing various complex industrial systems. Tuteja et al. [1-3] performed cost-benefit analysis of 2-unit system with different types of standby, failures and repairman. Rizwan et al. [4-9] carried out reliability analysis of 1-unit PLC system with hot standby; waste water treatment plant with inspection; and 2-unit system with various categories of repairman. Mathew et al. [10-16] estimated important reliability indices of 1-unit and 2-unit CC plant wherein different installation capacities and maintenance policies were considered. Padmavathi et al. [17-22] extensively analysed desalination plant focussing on major and minor failure, emergency shutdown, online repair, and priority to repair over maintenance. Rizwan et al. [23-24] extended the work for reliability analysis of desalination plant with season based shutdown and repair/maintenance on FCFS basis. Taneja et al. [25-26] discussed profit analysis of system with varying demand. Yaqoob Al Rahbi et al. [27-30] worked on the reliability and maintainability of three different systems in the aluminium industry. Taj et al. [31-35] studied the performance of 1-unit, 2-unit and 3-unit subsystems of a cable plant considering various maintenance categories and

priority to repair over preventive maintenance. Recently, Taj et al. [36-37] proposed two reliability models of a cable plant portraying specific season based operating strategies. The summer operating strategy, where the plant operates for 24 hours without resting machines, was discussed in Model-I [36]. Model-II [37] presented the winter operating strategy, where the plant operates for 16 hours followed by 8 hours rest period for the machines. Real maintenance data of the plant were used to estimate important reliability indices such as mean time to plant failure, availability of the plant, expected number of repairs, expected busy period of the repairman and profit incurred to the plant. Semi-Markov processes [38] and regenerative point techniques [39] were used to carry out the analysis. Simulated results were presented to demonstrate the effect of varying plant parameters on the reliability indices. There is scope of performing comparative analysis between the two reliability models of the cable plant.

Thus, this paper presents comparative analysis between the profits of the two reliability models of the cable plant, Model-I and Model-II. The behaviour of difference of profits of the two models with respect to various costs and different values of failure rate is demonstrated through graphs. The analysis is useful in deducing the suitability of one model over the other, under the following operating conditions and assumptions:

- The plant consists of five subsystems (A, B, C, D and E) operating in series.
- If a particular subsystem fails, the succeeding subsystems enter into the down state whereas the preceding subsystems continue to operate.
- The entire plant enters into the failed state once the first subsystem of the plant, arranged in series, fails.
- Repair is carried out upon failure.
- Repair work is completed before the plant enters into the rest state (for Model-II).
- Repair rates are taken as arbitrary.
- Failure rates are taken as exponential.

2 Model-I

For Model-I, the rates of transition from state S_i to state S_j are given in Table 1.

Table 1. Rates of transition for Model-I

$\begin{matrix} S_j \\ S_i \end{matrix}$	S_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}
S_0	0	λ_A	λ_B	λ_C	λ_D	λ_E	0	0	0	0	0
S_1	$g_A(t)$	0	0	0	0	0	0	0	0	0	0
S_2	$g_B(t)$	0	0	0	0	0	λ_A	0	0	0	0
S_3	$g_C(t)$	0	0	0	0	0	0	0	0	0	0
S_4	$g_D(t)$	0	0	0	0	0	0	λ_A	λ_B	0	0

S_5	$g_E(t)$	0	0	0	0	0	0	0	0	λ_B	λ_D
S_6	0	$g_B(t)$	0	0	0	0	0	0	0	0	0
S_7	0	$g_D(t)$	0	0	0	0	0	0	0	0	0
S_8	0	0	$g_D(t)$	0	0	0	0	0	0	0	0
S_9	0	0	$g_E(t)$	0	0	0	0	0	0	0	0
S_{10}	0	0	0	0	$g_E(t)$	0	0	0	0	0	0

S_{10}	0	0	0	0	$g_E(t)$	0	0	0	0	0	0	0
S_{11}	σ	0	0	0	0	0	0	0	0	0	0	0

Following measures of plant effectiveness in steady state are obtained (refer [37] for details):

$$\text{Mean time to plant failure, MTPF} = \frac{N}{D}$$

$$\text{Availability of the plant, } A_0 = \frac{N_1}{D_1}$$

$$\text{Expected busy period of the repairman, } B_0 = \frac{N_2}{D_1}$$

$$\text{Expected number of repairs, } R_0 = \frac{N_3}{D_1}$$

$$\text{Profit incurred to the plant, } P_1 = C_0 A_0 - C_1 B_0 - C_2 R_0$$

4 Comparison between the Two Models

Comparison of profits of Model-I and Model-II is done graphically for the particular cases and various conclusions are drawn.

Fig. 1 shows the behavior of difference of profits (P_1-P_2) with respect to revenue per unit up time (C_0) for different values of failure rate (λA).

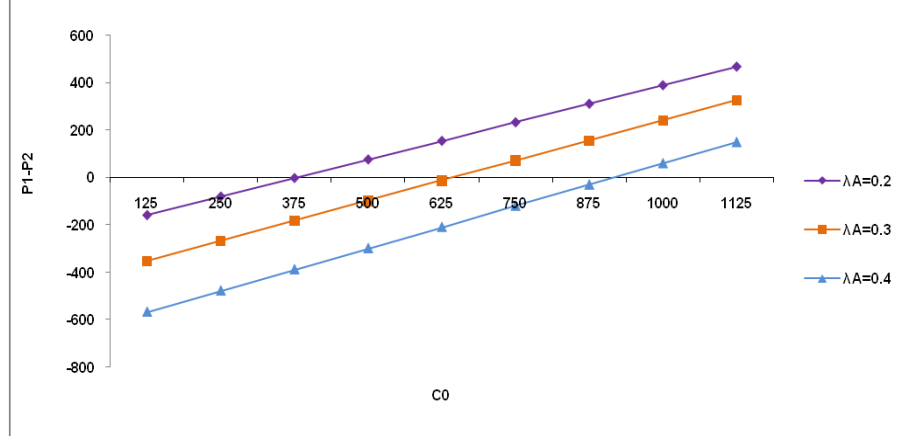


Fig. 1 Difference of profits (P_1-P_2) with respect to revenue per unit up time (C_0) for different values of failure rate (λA).

From the graph, the following can be concluded:

- The difference of profits (P_1-P_2) increases as the revenue per unit up time (C_0) increases.
- The difference of profits (P_1-P_2) is higher for lower values of failure rate (λA).

- (iii) For $\lambda_A = 0.2$, $P_1 - P_2 > \text{or} = \text{or} < 0$ accordingly as $C_0 > \text{or} = \text{or} < 375$. So, Model-I is better or worse than Model-II if $C_0 > \text{or} < 375$. Both models are equally good if $C_0 = 375$.
- (iv) For $\lambda_A = 0.3$, $P_1 - P_2 > \text{or} = \text{or} < 0$ accordingly as $C_0 > \text{or} = \text{or} < 643$. So, Model-I is better or worse than Model-II if $C_0 > \text{or} < 643$. Both models are equally good if $C_0 = 643$.
- (v) For $\lambda_A = 0.4$, $P_1 - P_2 > \text{or} = \text{or} < 0$ accordingly as $C_0 > \text{or} = \text{or} < 916$. So, Model-I is better or worse than Model-II if $C_0 > \text{or} < 916$. Both models are equally good if $C_0 = 916$.

Fig. 2 shows the behavior of difference of profits ($P_1 - P_2$) with respect to cost per unit time for which the repairman is busy (C_1) for different values of cost per unit repair (C_2).

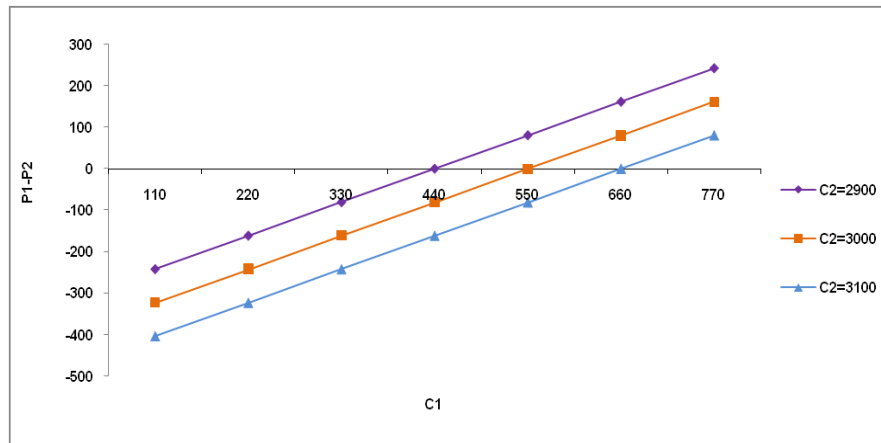


Fig. 2 Difference of profits ($P_1 - P_2$) with respect to cost per unit time for which the repairman is busy (C_1) for different values of cost per unit repair (C_2).

From the graph, the following can be concluded:

- (i) The difference of profits ($P_1 - P_2$) increases as the cost per unit time for which the repairman is busy (C_1) increases.
- (ii) The difference of profits ($P_1 - P_2$) is higher for lower values of cost per unit repair (C_2).
- (iii) For $C_2 = 2900$, $P_1 - P_2 > \text{or} = \text{or} < 0$ accordingly as $C_1 > \text{or} = \text{or} < 440$. So, Model-I is better or worse than Model-II if $C_1 > \text{or} < 440$. Both models are equally good if $C_1 = 440$.
- (iv) For $C_2 = 3000$, $P_1 - P_2 > \text{or} = \text{or} < 0$ accordingly as $C_1 > \text{or} = \text{or} < 550$. So, Model-I is better or worse than Model-II if $C_1 > \text{or} < 550$. Both models are equally good if $C_1 = 550$.
- (v) For $C_2 = 3100$, $P_1 - P_2 > \text{or} = \text{or} < 0$ accordingly as $C_1 > \text{or} = \text{or} < 660$. So, Model-I is better or worse than Model-II if $C_1 > \text{or} < 660$. Both models are equally good if $C_1 = 660$.

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